THE EFFECTS OF EXTINCTION ON RESPONSES TO GENERALIZED AND CONDITIONED STIMULI IN PIGEONS

by

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Introduction

The expression "stimulus generalization" has been used to designate both an effect and the procedure used to study it. The effect may be described as a learned change in the response to one stimulus or set of stimuli, the generalized stimulus (GS), which results from training with a similar stimulus (S+). On the other hand, "stimulus generalization" may designate the procedure used to study this effect. This procedure consists of two steps: (1) training the subject under one set of conditions and then (2) testing the subject's performance under a similar set of conditions.

Pavlov (1927) was the first to study stimulus generalization experimentally in his investigation of conditioned reflexes in dogs. Later Hovland (1937a) and others explored generalization along various stimulus dimensions and obtained a graded generalization of response to sounds and to visual stimuli with the response declining with increasing changes in the pitch of the sound, or in the brightness or hue of the visual object (see Mackintosh, 1974; Rilling, 1977). Thus, the outstanding feature of the large majority of studies of stimulus generalization is the orderliness of the gradients; that is, the

monotonic relationship between the size of the decrement in responding and the difference between training and test values of the stimuli (Honig & Urcuioli, 1981).

For most generalization gradients, the vertical axis represents some measure which is assumed to be a positive monotonic function of the tendency to make the conditioned response. Several different measures, such as response amplitude, response latency, rate or probability of occurrence of the response, and its resistence to extinction have all been used. However, a limitation of these measures as pointed out by Miller & Murray (1952), Perkins & Weyant (1958), and Reinhold & Perkins (1955) and more recently by D. Blough (1965), P. Blough (1972), and Mackintosh (1974) is that they all have serious scaling problems which have been largely ignored. There is a need for a way of transforming these different response measures into ratio scale measures of the strength of response tendencies (Blough, 1965; Mackintosh, 1974).

The response measures that are usually obtained in stimulus generalization studies can be interpreted in either of two ways. The first is as quite specific to the particular conditions of the experiment. In this case no inferences can be made from these specific

gradients to (a) other test conditions or (b) other types of response measures. Findings which are limited to specific conditions do not apply to even slightly different conditions, and the results obtained using one response measure do not indicate what will be found with other response measures. The second is as a response measure which can be specified only on an ordinal scale. If the scale on the vertical axis is only an ordinal measure, then it does not make sense to refer to the shape or slope of the gradients. Any transformation which maintains order is permissible for ordinal measures. Any monotonic function may be substituted for another with a slope in the same direction. Unless two gradients actually cross, one cannot conclude that their slopes are different. Only if both scales have at least interval properties is it meaningful to refer to the shape or slope of the gradients.

Thus, there is need for a response measure which remains consistent under different test conditions and with different types of responses. A measure which may fulfill these conditions is the strength of the expectation (E) of the reinforcer (S*). The advantage of using this measure is that it may be possible to generalize it not only to different experimental

conditions and different response measures but also to different reinforcers. In the definition of this response measure and throughout this thesis, "expectation" will refer to the notion that the occurrence of a response during conditioning implies that as a result of conditioning, the subject acquires an expectation that a reinforcer (S*), in the broadest use of the term, will follow the response. In this usage, a reinforcer (S*) is any non-neutral stimulus which serves as an unconditioned stimulus (US) in Pavlovian conditioning or which is contingent on the response in instrumental or operant procedures.

Another way in which generalization gradients are unsatisfactory is with respect to the method usually employed in presenting and analyzing the results. The main problem is that the measures often used are the average of many non-reinforced test trials. Thus, in extinction tests, two different factors which contribute to these response measures are confounded. These factors are (1) the response measure on initial test trials and (2) its extinction rate (Blough, 1965). Because these two factors are confounded, this single, averaged response measure is inadequate. To deal with this problem, a continuous response measure can be recorded. From this, separate indices of (1) the

initial strength of response tendencies and (2) the rate of change in strength of response tendencies during extinction may be obtained. Whether these two indices are correlated may then be determined empirically. In the present study, separate indices were obtained for the initial strength and the rate of extinction of responses to the conditioned stimuli (S+s) and the generalized stimuli (GSs) by using generalization tests to obtain "extinction curves." This method permits one to obtain separate measures of the initial response strength and its rate of extinction. However, it should be noted that these indices are still subject to the same scaling problems with respect to the response measure on the vertical axis as generalization gradients.

There are both empirical and theoretical reasons to suspect that both response tendencies and expectations are less stable in the presence of novel test stimuli than in the presence of training stimuli, and that the greater the dissimilarity of the training and test stimuli the less resistant expectations are to changes in strength. Several studies, for instance, Friedman and Guttman (1965), Hoffman (1965), Hoffman and Fleshler (1961), Hovland (1937b), Jenkins and Harrison (1960), Thomas and Barker (1964), and Wickens,

Schroder, and Snide (1954), have obtained more rapid extinction of responses to generalized test stimuli than of responses to the training stimuli. Furthermore, they found that the greater the distance was between the training stimulus and the generalized test stimulus, the more rapid the extinction. Unfortunately, in all of these experiments the y-axes of the extinction curves were measured on scales which should be interpreted either as specific to the conditions of the particular experiment or as only ordinal measures. Therefore, the evidence suggesting that responses extinguish more rapidly the greater the difference between training and test stimuli cannot be safely generalized to other conditions. Furthermore, Grant and Schiller (1953) and Kalish and Haber (1963) failed to obtain faster extinction of responses to generalized test stimuli than to training stimuli. Thus, the question of how similarity of training and test stimuli affects rate of extinction of responses can only be determined if response strength is measured on a scale with at least interval properties.

The method used in the present study to measure the strength of response tendencies on a ratio scale is based on the matching relationship obtained during concurrent schedules (Herrnstein, 1970). In concurrent

schedules, two or more responses are simultaneously available with different schedules of reinforcement in effect for each response. The matching relationship refers to matching relative rates of responding (or relative amounts of time allocated to a response) to the relative rates of reinforcement on concurrent schedules. Ordinarily, matching is studied using concurrent schedules consisting of two variable-interval (VI) components (de Villiers, 1977).

A review of the relevant research reveals that the matching relationship is usually closely approximated when concurrent, random-interval (RI) schedules (in which the probability of reinforcement becoming available is constant) are employed (de Villiers, 1977). However, good response matching usually requires a change-over delay (COD) of at least 2 s. A change-over delay (COD) refers to a contingency which prevents reinforcement of a response on one component schedule until some amount of time has elapsed since the last response on the other component. A COD is usually employed to discourage excessive switching between components. Relative rates during concurrent schedules as an index of the strength of response tendencies has the further advantage that any fluctuation in the rate of responding to the test

stimulus which is not due to the strength of the response tendencies will be accompanied by a similar effect on the rate of responding to the comparison stimulus.

The Herrnstein matching relationship provides the rationale for deriving ratio scale measures of the strength of expectations of reinforcers and of the strength of response tendencies. In operant procedures, the strength of an expectation may be reflected in performance at steady-state. When the subject has learned the contingencies, the strength of the expectation of an event will be defined as equal to the rate of occurrence of that event (that is, the obtained rate of reinforcement). The scheduled rate of reinforcement may be used as an approximation of the obtained rate of reinforcement when variable-interval (VI) schedules are used because with VI schedules the obtained rate of reinforcement approximates closely the scheduled rate of reinforcement (Herrnstein, 1961). It follows from this that the steady-state strength of the expectation of the reinforcer, E (S*), during a RI schedule is a linear function of the scheduled rate of reinforcement. Thus, if E (S*/min) is defined as equal to the obtained S*/min when the expectation accurately reflects the contingencies, then the strength of E (S*)

at steady-state can be measured on a ratio scale derived from the scheduled rate of reinforcement. Furthermore, because the strength of response tendencies is a linear function of the expectation of a reinforcer, the strength of a response tendency also may be specified on a ratio scale.

Specifically, the basis for using the relative response rates as measures of the strength of E (S*) and of the strength of response tendencies is the response matching relationship which may be expressed as

$$Ra / Rb = S*a / S*b \qquad (1)$$

where Ra and Rb are the rates of occurrence of two responses, and S*a and S*b are the rates of reinforcement delivered for each. Because the expectation of the reinforcer is a linear function of the scheduled rate of the occurrence of the reinforcer, Equation 1 becomes:

$$E\ (S*a) = S*b\ (Ra / Rb) \qquad (2)$$

so long as S*b remains the same throughout both the training and test trials. Thus, because the scheduled rate of reinforcement to the comparison stimulus (S*b) is always a constant, E (S*a) is a linear function of Ra / Rb.

Furthermore, this measure of the strength of

response tendencies (Ra / Rb) can provide a continuous index of the strength of the E (S*a) while the expectation is changing, as during extended testing for generalization during extinction. If the strength of one steady-state response tendency or expectation (that to the comparison stimulus) is known, the strength of another response tendency which is not at steady-state (that to the generalized stimulus) can be determined because when the responses are concurrently available, the strength of their expectations are proportional to their rates of occurrence. In other words, if E (S*b) is held constant by maintaining the same RI reinforcement schedule for Rb at all times, then a concurrent schedule in which one component is the RI schedule for Rb (the comparison stimulus) may be employed to measure the strength of E (S*a). Thus, the matching relationship provides a means of measuring both the initial rate and the rate of extinction of E (S*a) on a scale with ratio properties.

The present experiment was designed to apply the ratio scale measure of the strength of expectations of reinforcers to the rate of extinction of expectations of response contingent reinforcement during stimulus generalization tests. Specifically, the hypothesis was that the rate of extinction of expectations of

reinforcement would be faster as the distance (dissimilarity) increased between the training stimuli (S+s) and the generalized stimuli (GSs).

In the present experiment, seven stimuli (Stimuli 1-7) in order along the hue dimension were employed, two stimuli (3 & 5) were S+s and the other five stimuli were GSs. Subjects were trained on the two S+s and were tested during extinction in generalization tests using all seven stimuli.

Method

Subjects

Seven experimentally naive pigeons of mixed breed obtained locally served as subjects. Pigeons were maintained at 80% of free-feeding body weights by mixed grain (wheat and milo) obtained during experimental sessions and, when necessary, by supplemental feedings shortly after the session. Birds were individually housed in a colony room under 16 hr/8 hr light/dark cycle, and had free access to grit and water.

Apparatus

A test chamber measuring 36 cm high, 37 cm wide by 36 cm deep was used. The three-key chamber was painted black throughout. The box was equipped with three translucent Gerbrand pigeon-response keys which were mounted with 5 cm between each key and 22 cm above the false floor. Only the center and the left keys were used in the present experiment. The center key could be transilluminated with a white X on a black background. A Bausch and Lomb monochromator (grating 1350 grooves/mm--catalog number 33-86-02) with a tungsten-halogen light source using fiber optics could transilluminate the left key with a circle of light 3 mm in diameter in the center of the key. The setting of the monchromator could be changed automatically to

present one of seven different stimuli [Stimulus 1 (500 nm), Stimulus 2 (510 nm), Stimulus 3 (522 nm), Stimulus 4 (536 nm), Stimulus 5 (550 nm), Stimulus 6 (562 nm) or Stimulus 7 (578 nm)] on the left key. The stimuli were selected to be separated by approximately equally discriminable wavelength differences or steps (10 to 15 nm apart) along the hue dimension using Wright's (1978) equal-hue discriminability scales for the pigeon. Reward was provided by 3 s access to grain (a mixture of 50% wheat and 50% milo) from a Lehigh Valley grain feeder through a 5 X 4 cm opening located 14 cm below the center key. During grain presentation the feeder was illuminated by a 1.1-Watt, 24-Volt incandescent lamp and all other lights in the chamber were extinguished. A white houselight (6-Watt lamp) was mounted above a 7 X 10 cm rectangular translucent, plastic window in the ceiling of the box. White noise delivered through a loudspeaker located in the ceiling and noise from an exhaust fan masked extraneous sounds.

The response keys were operated by a minimum force of approximately .1 N. When a response key was illuminated, each peck to that key produced an audible relay click. A 7 X 28 cm window in the door of the chamber permitted observation of the birds during training sessions. Programming and recording equipment

were located in an adjacent room. Control of the experimental equipment as well as data recording was performed by a PDP/8a computer utilizing Timeshare SuperSKED software (Snapper, Kadden, and Inglis, 1982).

Procedure

All birds were trained on two stimuli (S+s), Stimulus 3 (522 nm), a medium green to the human observer, and Stimulus 5 (550 nm), a yellowish-green to the human observer. They were then tested in extinction with Stimuli 1-7 [in which Stimuli 3 (522 nm) and 5 (550 nm) were S+s and Stimuli 1 (500 nm), 2 (510 nm), 4 (536 nm), 6 (562 nm), and 7 (578 nm) were generalized stimuli (GSs)].

Each bird was first exposed to a pretraining procedure which began with magazine training. Magazine training (Phase 1) consisted of presentation of the feeder until the bird broke the photo-beam by putting its head into the feeder. In this phase, the feeder remained up for 10 s after the photo-beam was broken. The presentation of the feeder for 10 s was considered one reinforcement. Except during feeder presentation when only the feeder light was on, a white houselight illuminated the chamber throughout pretraining. Sessions of magazine training were terminated when the birds had collected 36 reinforcements or after 90 min

had elapsed.

During Phase 2, each bird was given an autoshaping procedure which was designed to establish pecking on both the center key (black with white X) and the left key (Stimuli 3 and 5 alternately presented). In the autoshaping procedure, the stimulus remained on the key until the pigeon pecked that key or until 4 s had elapsed. In either case food presentation immediately followed. Phase 2 was completed when a bird had pecked each key and each color on the left key at least five times.

Following autoshaping, each pigeon advanced through three phases of pretraining designed to increase pecking rates and establish frequent switching between the two keys. Phase 3 was designed to establish regular pecking to each of the two response keys. Both keys were illuminated simultaneously and one became effective. If the bird pecked the effective response key, then both response keys and the houselight were darkened and the hopper was illuminated and presented for 3 s. However, if the effective key was not pecked within the initial 10 s, then the ineffective key was darkened, leaving only the effective key illuminated until the bird pecked that key. A peck to the effective key darkened the key and

produced a reward of a 3 s grain presentation. The left key was effective on a random half of the trials and the middle key was effective on the other half of the trials. The session was terminated after 40 food presentations.

Phase 4 of pretraining was intended to equalize pecking rates on the two response keys. On each trial, both the center key (black with white X) and the left key (Stimuli 3 and 5 alternately presented) were simultaneously illuminated. An independent concurrent VI-3 s, VI-3 s schedule was presented on the center and left keys. On an independent concurrent schedule, reinforcement set-up on one schedule has no effect on the clock for the other schedule. Every .06 s there was a .02 probability that reinforcement would become available on each key. The session was terminated when 36 reinforcements had been collected.

Phase 5 of pretraining was intended to further equalize pecking rates on the two keys. As before, the stimuli on both keys were presented simultaneously, one on each key; however, the schedule was changed to an interdependent concurrent VI-48 s, VI-48 s on the response keys. In an interdependent concurrent schedule, when reinforcement is set-up on one schedule, the clock is stopped on both schedules (Pliskoff,

1971). This type of procedure permits the experimenter to control the exact proportion of reinforcements for pecks to each key and forces the birds to respond on both schedules if they are to continue to collect food. A changeover delay (COD) of one second was programmed on each key to discourage excessive switching between the keys. Every .06 s there was a .005 probability that a reinforcement would become available on one key or the other (VI-48 s). Again, the sessions were terminated when 36 reinforcements had been collected.

The final training phase (Phase 6) was designed to stabilize pecking rates to the two keys. Again, the stimuli were presented simultaneously on both keys with the white stimulus on the center key and the colored stimuli alternating on the left key. An interdependent concurrent VI-240 s, VI-240 s schedule was presented on the response keys. A 4 s COD was programmed on each key. Trials began with simultaneous illumination of both response keys and lasted for 60 s. A 20 s intertrial-interval (ITI) was programmed during which all lights were darkened, the VI clock stopped, and the keys were ineffective. Every .12 s during trials (while the stimuli were presented on the keys), there was a .001 probability that a reinforcement would become available on one of the two keys if a

reinforcement was not already available. A random half of the reinforcements were assigned to each key in each block of six trials. To avoid counting key bounces as pecks, a debounce (contact breaks less than .2 s after the previous one were not counted) was programmed on each key during the final training and testing sessions. Each bird was trained on the center key (black with white X) and the left key (alternating between Stimuli 3 and 5). The sessions were terminated when 48 reinforcements had been collected. All birds were trained for 12 consecutive days of Phase 6 prior to the testing phase.

The reminder part of the first testing session consisted of a shortened version of the final training session. The reminder part was completed as soon as the birds had collected 6 reinforcements. The second part of the testing session followed. The schedule during testing was a concurrent VI-240 s, EXT with a (constant probability) VI-240 s on the center key (black with white X) and extinction (EXT) on the left key (Stimuli 1-7). Each of the seven stimuli were presented once per cycle and there were 14 cycles (98 trials) per testing session. Furthermore, a 7 X 7 Latin square was used to determined the seven different sequences of the stimuli; thus, the seven birds were

counterbalanced for the sequence of presentations of the seven stimuli. Therefore, all birds were tested in extinction on the two training stimuli (S+s) and five generalized stimuli (GSs). A 4 s COD was programmed on the center key. Trials consisted of simultaneous illumination of both response keys for 60 s. During the 20 s ITI, the response keys and houselight were darkened. Every .24 s there was a .001 probability that a reinforcement would become available on the center key (VI-240 s). No reminder training was given on subsequent testing sessions which were each terminated after 98 test trials (14 cycles) had been presented. Sessions were continued until the number of responses to each of the stimuli dropped below 100 pecks during the entire session. The number of responses to the center key (black with white X) and the left key (Stimuli 1-7) during each presentation of a pair of stimuli were counted. Totals for each of these response categories also were recorded.

Results

Table 1 presents both the relative response rates (Ra / Rb where Ra is pecks to the training stimuli and Rb is pecks to the comparison stimulus) for the final training session and for the average of the last three training sessions for each of the birds. In addition, Table 1 shows the mean relative response rates for all birds for both the final training session (.97) and for the average of the last three sessions (1.03). These values indicate that the birds were close to matching (1.0) at the end of the final training. Unfortunately, the relative response rates for the reminder or retraining periods that immediately preceded the test trials on the final test session were not obtained because of programming limitations. In addition, results are reported only for the first test session because with one exception the birds made few pecks to the test stimuli during the second test session.

Each bird's expected rates of reinforcement to the test stimulus (S*b Ra / Rb) were calculated for each trial. The scheduled rate of reinforcement to the comparison stimulus, S*b, was equal to .25 reinforcements / min because the birds received on the average one reinforcement every four minutes (VI-240 s). Furthermore, these expected rates of reinforcement

Table 1

Relative Pecking Rates (Ra/Rb) for Both the Final Training Session and the Average of the Last Three Training Sessions

	Final Training	
Birds	Final Training Session	Average of Last Three Training Sessions
17	1.03	0.82
18	0.87	1.09
19	1.02	1.12
20	0.95	0.85
21	0.89	1.04
22	1.16	1.25
23	0.88	1.05
Mean for All Birds	0.97	1.03

were bound by the constraint that Rb could not equal zero; thus, if, during a trial, the bird did not peck the comparison key, no expected rate of reinforcement was assigned for that trial. However, in all but one instance (which consisted of a single peck to the test stimulus) when there were no pecks to the comparison stimulus during a trial, there were also no pecks to the respective test stimulus. The pecking rates to each of the stimuli for each trial and the expected rates of reinforcement for each bird during their first test session are presented in the Appendix.

To analyze the data, it seemed appropriate to group the seven stimuli into pairs: Stimuli 3 & 5 (training stimuli), Stimuli 2 & 6 (each one-step from the training stimuli), Stimuli 1 & 7 (two-steps from the training stimuli) and Stimulus 4. Stimulus 4 was omitted from further analysis because there was no a priori basis for determining whether the response tendency to that stimulus would be stronger or weaker than the response tendency to the training stimuli. This procedure converted the comparable pairs of stimuli into an ordered variable. Figure 1 shows the extinction curves for the three pairs of stimuli and for Stimulus 4.

Using a General Linear Model procedure (GLM) which

Figure Caption

Figure 1. Relative rates of extinction by blocks of 5 trials for the training stimuli, the pair one-step removed, the pair two-steps removed, and Stimulus 4.

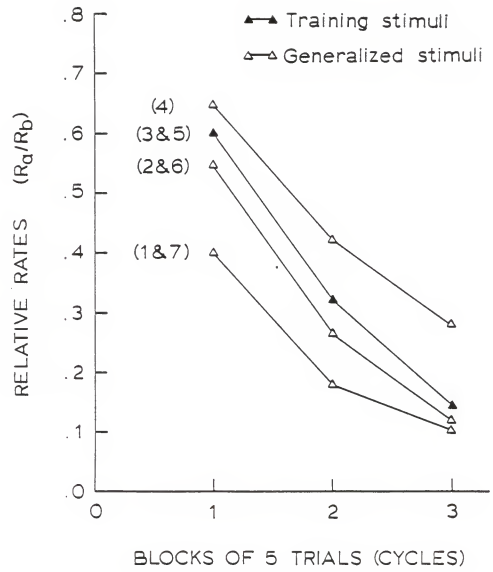

Training stimuli
Generalized stimuli
(4)
(3&5)
(2&6)
(1&7)
RELATIVE RATES (R_a/R_b)
.8
.7
.6
.5
.4
.3
.2
.1
.0
0
1
2
3
BLOCKS OF 5 TRIALS (CYCLES)

Table 2

Results of 3 X 14 X 7 (Stimulus X Cycle X Bird) ANOVA Using the GLM (General Linear Model) Procedure

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	p-Value
Bird	6	1.560	.260	28.97	$p < .0001$
Cycle	13	2.057	.158	17.63	$p < .0001$
Bird X Cycle	78	1.386	.018	1.98	$p < .001$
Stimulus	2	0.210	.105	11.68	$p < .0001$
Cycle X Stim	26	0.248	.010	1.06	$p > .05$
Error	157	1.409	.009		
Total	282	6.870			

can deal with missing data and ordered variables, a 3 X 14 X 7 (Stimuli X Cycle X Bird) analysis of variance (ANOVA) was performed and least square means were estimated for stimuli by cycle. A cycle consisted of the presentation of all of the seven stimuli in a particular order whereas a trial referred to each 60 s presentation of a test stimulus. The model employed by the GLM procedure accounted for approximately 80% of the variance of the dependent variable (R2 = .795). Table 2 presents the results of the ANOVA generated by the GLM procedure. The effect of Stimuli was significant, $\underline{F}(2,157) = 11.68$, $p < .001$, which indicates that some of the expected rates among the three pairs of stimuli differed significantly. In light of this result, further analysis of the Stimulus variable seemed appropriate.

To fit the data to a model, a curve-fitting procedure was employed. From inspection of the data, a simple decay-function of the form:

$$R(N) = A + C \times 10^{-BN} \qquad (3)$$

where A = the asymptote, B = the relative rate of decrease (rate of approach to asymptote), C = the maximum (intercept at cycle zero), and N = cycle number, seemed appropriate. The simple decay-function has been employed by several investigators, such as

Estes and Burke (1953), Hull (1943), and Rescorla and Wagner (1972), to describe extinction curves. Using both non-linear and Marquardt's (iteration) methods, the least square means (across birds) that were obtained from the GLM procedure were used to estimate the different parameters of the decay-function for each of the three pairs of stimuli. From these parameters, three fitted curves also were calculated.

Table 3 presents the three parameters (A, B, C) which were estimated for each of the three sets of stimuli along with their 95% confidence intervals. The three estimates for parameter A (asymptote) were slightly less than zero; however, they were assigned a value of zero on an a priori basis. Parameter B represented the relative rate of decrease or the rate of approach to the asymptote. The three estimates of parameter B were similar (training stimuli = .059, pair one-step removed = .060, and pair two-steps removed = .063) and their 95% confidence intervals almost completely overlapped; these results failed to indicate any differential extinction rate among the three pairs of stimuli.

Results of the three estimates from the decay-function model for parameter C (intercept) were .844 for the training stimuli, .780 for the pair of

Table 3

Using the Decay-Function Model, Estimated Values for the Three Paramaters (A, B, C) and Their 95% Confidence Intervals for the Three Pairs of Stimuli

Parameter	Pairs of Stimuli	Estimates of Parameters	Confidence Intervals
	3 and 5	0.000	-0.512 to 0.512
A	2 and 6	0.000	-0.400 to 0.400
	1 and 7	0.000	-0.152 to 0.152
	3 and 5	0.059	-0.028 to 0.146
B	2 and 6	0.060	-0.017 to 0.137
	1 and 7	0.063	0.019 to 0.106
	3 and 5	0.844	0.464 to 1.228
C	2 and 6	0.780	0.480 to 1.080
	1 and 7	0.560	0.444 to 0.672

stimuli one-step removed, and .560 for the pair of stimuli two-steps removed. First, neither the intercept for the training stimuli (.844 with confidence interval of .464 to 1.228) nor the relative response rates (Ra / Rb) from the final training sessions differed reliably from 1.0. Secondly, the difference between the intercepts for the training stimuli (.844) and the pair one-step removed (.780) was small with their 95% confidence intervals almost completely overlapping. However, the differences were larger when the intercepts for the training stimuli (.844) and the pair one-step removed (.780) were compared with the pair two-steps removed (.560), and their 95% confidence intervals did not show as much overlap.

Figures 2 through 4 depict both the fitted curves estimated from the parameters and their respective actual curves for each of the three pairs of stimuli: Figure 2 depicts the pair of training stimuli; Figure 3 shows the pair of stimuli one-step removed; and Figure 4 presents the pair of stimuli two-steps removed. Figure 5 presents the three fitted curves, estimated from the decay-function model for the three pairs of stimuli, in the same figure for comparison.

Figure Caption

Figure 2. The curve for the actual relative rates per cycle compared with the fitted curve estimated from the decay-function model for the pair of training stimuli.

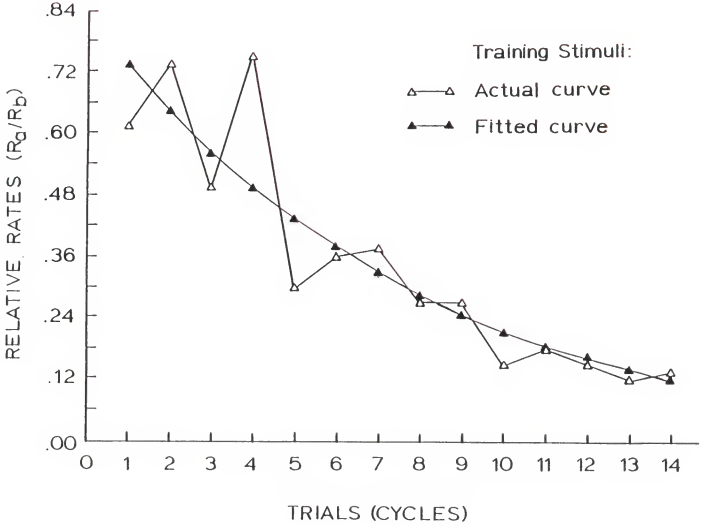

.84
.72
.60
.48
.36
.24
.12
.00
RELATIVE RATES (R_a/R_b)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
TRIALS (CYCLES)
Training Stimuli:
Actual curve
Fitted curve

Figure Caption

Figure 3. The curve for the actual relative rates per cycle compared with the fitted curve estimated from the decay-function model for the pair of stimuli one-step removed.

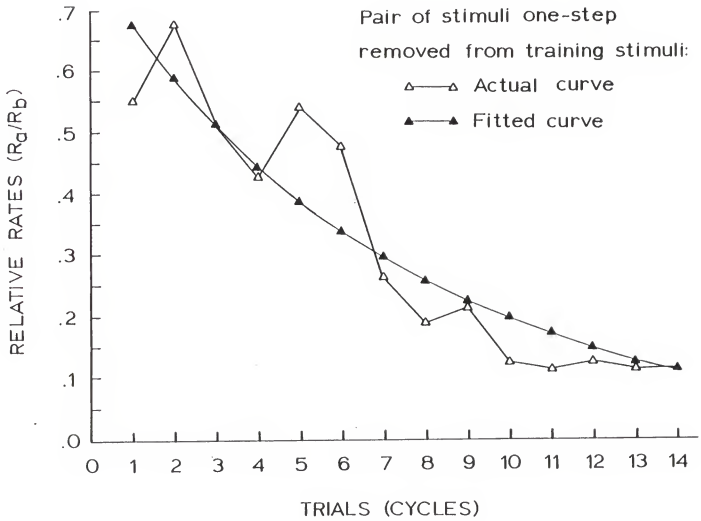

Pair of stimuli one-step
removed from training stimuli:
Actual curve
Fitted curve
RELATIVE RATES (R_a/R_b)
.7
.6
.5
.4
.3
.2
.1
.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
TRIALS (CYCLES)

Figure Caption

Figure 4. The curve for the actual relative rates per cycle compared with the fitted curve estimated from the decay-function model for the pair of stimuli two-steps removed.

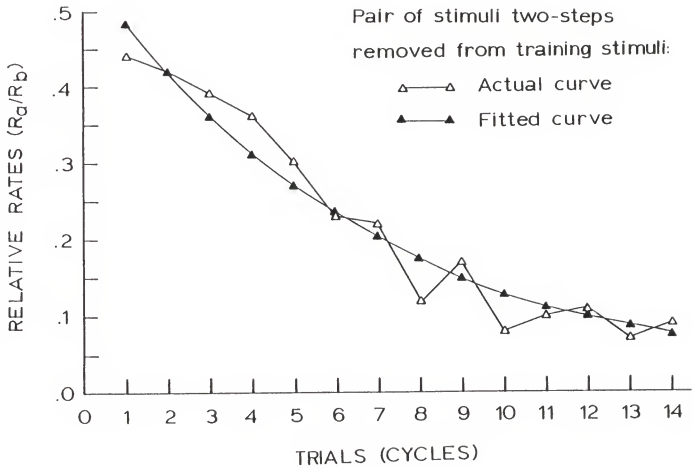
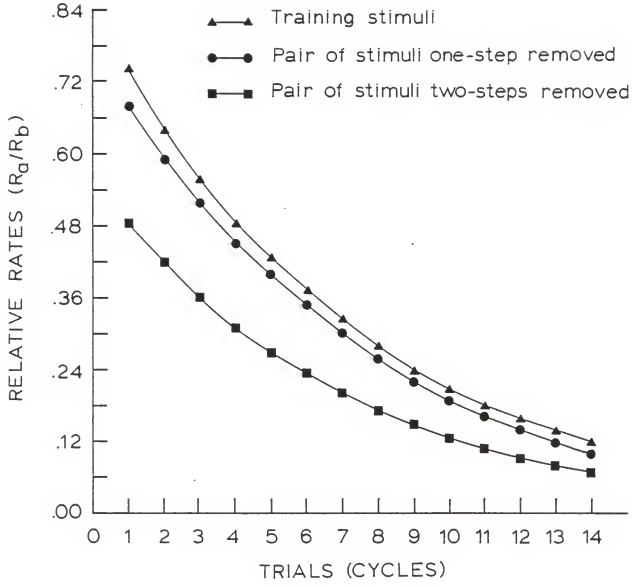

Pair of stimuli two-steps
removed from training stimuli:
Actual curve
Fitted curve
RELATIVE RATES (R_a/R_b)
.5
.4
.3
.2
.1
.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
TRIALS (CYCLES)

Figure Caption

Figure 5. The fitted curves estimated from the decay-function model for the three pairs of stimuli.


Training stimuli
Pair of stimuli one-step removed
Pair of stimuli two-steps removed
RELATIVE RATES (R_a/R_b)
.84
.72
.60
.48
.36
.24
.12
.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
TRIALS (CYCLES)

Discussion

The overall relative rates for the pair of stimuli two-steps removed from the training stimuli showed reliable differences when compared with the other two pairs of stimuli. Furthermore, results for the initial rates or parameter C (intercept) showed substantial differences when both the training stimuli and the pair one-step removed was compared with the pair two-steps removed. Because the initial response tendency to the pair one-step removed and especially to the pair two-steps removed was less than to the training stimuli, it can be concluded that the birds were able to discriminate between the training stimuli and the other two pairs of stimuli.

The most important finding of the present study was that the extinction rates were similar for all three pairs of stimuli. The three fitted curves (Figure 5) differed mainly in their initial rates and not in their relative rates of extinction. Because the estimates of the three B parameters were so close, none of the differences between the rates of extinction for the three pairs of stimuli approached significance. Thus, the hypothesis that the rate of extinction of expectations of reinforcement would be faster as the distance (dissimilarity) increased between the training

and generalized stimuli was not supported. However, the slight differences found in the relative rates of extinction were in the direction of the hypothesis. It also may be concluded that for conditions in which there is no differential extinction rate, using the average of many non-reinforced test trials as a single response measure during extinction tests would not present a problem.

As mentioned previously, Friedman and Guttman (1965), Wickens, Schroder, and Snide (1954) and others obtained a faster extinction rate to the generalized stimuli than the training stimuli; however, they did not obtain measures of the strength of response tendencies which have ratio scale properties. The results of this experiment are similar to the findings of Grant and Schiller (1953) and Kalish and Haber (1963) who failed to find faster extinction of responses to generalized test stimuli than to training stimuli. However, because the present experiment appears to be the first to employ ratio scale measures, no conclusions can be drawn from comparisons with the previous research.

Using two training stimuli instead of the usual one may provide an explanation of the failure of this experiment to find faster extinction rates to

generalized stimuli than to training stimuli. Kalish and Guttman (1957) also used two training stimuli and their data showed flatter generalization gradients. This effect was even more pronounced when three training stimuli were employed (Kalish & Guttman, 1959). Thus, flatter gradients may tend to mask the significant differences in the size of the generalization decrements between the pairs of stimuli.

A related explanation involves the possibility that the generalized stimuli selected for this experiment were not far enough away from the training stimuli; thus, they might not be sensitive enough to pick up the differential extinction rates which might have been obtained had there been only one training stimulus. Possibly if generalized stimuli had been selected which would have shown less than a 50% decrement between the training and the generalized stimuli, the typical differential extinction rates might have been found. However, if the generalized stimuli are chosen too far away from the training stimuli, there might not be enough initial generalization to the stimuli to obtain satisfactory extinction curves during generalization tests.

The decay-function model was found to estimate curves which were a reasonable fit to the actual data

curves. This model, using the various parameters estimated from the data for each of the three pairs of stimuli, suggests the possible shape and slope of extinction curves for stimulus generalization. If the results of other studies obtain curves which can be described by the same general decay-function, it would lend considerable support to the model. However, it is possible that the data would be fit by a similar function just as well.

Although the method of deriving a ratio scale measure of the strength of response tendencies using the matching relationship seems to have been useful and effective in this experiment, more experiments are needed to test the generality of the relationships using this scale of measurement. Studies using different types of stimuli, different schedules, and different reinforcers would be valuable.

The finding that there was a similar extinction rate among the three pairs of stimuli presents a problem for explaining discrimination learning in terms of generalization. In fact, the similarity of the extinction rates is somewhat surprizing in view of the finding that sometimes early in discrimination learning, there seems to be virtually complete generalization from S+ to S- and vice versa whereas

later in training almost no such generalization occurs. In contrast, this experiment found no change in generalization throughout extinction. Thus, some other mechanism besides generalization, for example, attentional change (Lawrence, 1949, 1950; Sutherland & Mackintosh, 1971), may be needed to explain discrimination learning.

In conclusion, the main findings in this study include lack of support for a differential extinction rate between the training and generalized stimuli and that a decay-function model appears to fit the data reasonably well. If with additional research these results are confirmed, they will need to be integrated into the analysis of stimulus generalization and those learning processes which require it as an explanation.

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Appendix

Table A-1

The Pecking Rates to the Test Stimulus (Ra) and the Comparison Stimulus (Rb) on Each Trial for Bird 17

		Test Stimuli						
Cycle		1	2	3	4	5	6	7
1	Ra	26	48	21	33	59	45	00
	Rb	74	43	83	67	40	48	00
2	Ra	46	29	38	32	36	37	45
	Rb	46	50	49	62	62	57	56
3	Ra	31	29	35	20	20	24	47
	Rb	64	55	55	39	59	71	40
4	Ra	43	20	24	44	25	22	34
	Rb	42	46	51	50	35	40	58
5	Ra	27	41	23	29	25	47	44
	Rb	49	43	48	42	50	35	39
6	Ra	27	21	23	10	01	36	12
	Rb	48	56	66	20	00	50	18
7	Ra	16	24	27	19	28	30	45
	Rb	33	28	20	26	47	48	50
8	Ra	06	12	23	14	10	11	16
	Rb	75	60	50	61	47	54	50
9	Ra	31	06	15	13	26	19	22
	Rb	40	31	59	53	35	50	51
10	Ra	00	00	00	00	00	00	07
	Rb	00	00	00	00	00	00	52
11	Ra	00	00	00	00	00	00	00
	Rb	00	00	00	00	00	00	00
12	Ra	23	28	16	07	10	12	01
	Rb	41	55	55	60	85	90	01
13	Ra	14	05	14	42	10	09	13
	Rb	54	60	93	42	61	54	51
14	Ra	05	00	00	00	00	00	14
	Rb	55	00	00	00	00	00	54

Table A-2

The Pecking Rates to the Test Stimulus (Ra) and the Comparison Stimulus (Rb) on Each Trial for Bird 18

		Test Stimuli						
Cycle		1	2	3	4	5	6	7
1	Ra	32	31	00	20	22	28	31
	Rb	39	43	00	32	35	34	35
2	Ra	20	17	15	19	07	43	06
	Rb	32	32	38	32	30	34	41
3	Ra	18	19	07	04	13	04	27
	Rb	33	32	35	31	31	36	35
4	Ra	14	08	25	10	11	20	09
	Rb	34	37	31	34	34	36	39
5	Ra	10	16	09	18	06	13	20
	Rb	34	32	34	34	33	35	33
6	Ra	11	19	16	14	06	16	08
	Rb	38	38	33	39	34	43	38
7	Ra	08	07	05	14	10	08	07
	Rb	46	36	37	38	36	38	41
8	Ra	10	10	14	19	07	10	03
	Rb	36	41	39	41	39	40	44
9	Ra	19	14	12	16	17	04	02
	Rb	40	46	38	36	42	43	44
10	Ra	10	11	04	11	13	04	08
	Rb	37	39	36	32	39	43	39
11	Ra	05	07	07	14	19	10	04
	Rb	34	34	33	38	31	38	35
12	Ra	12	06	12	14	01	00	00
	Rb	35	34	30	34	34	38	38
13	Ra	01	00	09	04	06	01	00
	Rb	32	38	32	37	37	38	39
14	Ra	02	12	02	08	03	01	00
	Rb	39	34	30	39	35	37	34

Table A-3

The Pecking Rates to the Test Stimulus (Ra) and the Comparison Stimulus (Rb) on Each Trial for Bird 19

		Test Stimuli						
Cycle		1	2	3	4	5	6	7
1	Ra	11	09	10	14	00	08	05
	Rb	13	26	24	28	00	23	27
2	Ra	16	14	24	23	14	08	08
	Rb	34	24	18	21	22	14	23
3	Ra	16	24	09	20	08	13	06
	Rb	13	17	31	22	15	28	33
4	Ra	09	15	13	17	23	07	08
	Rb	16	14	29	22	13	27	22
5	Ra	06	07	07	07	12	06	06
	Rb	15	35	32	18	28	20	24
6	Ra	05	18	14	09	10	17	06
	Rb	27	26	22	23	21	24	24
7	Ra	05	07	11	05	14	12	02
	Rb	24	24	21	24	31	25	28
8	Ra	10	06	06	12	06	10	09
	Rb	32	20	13	30	33	22	21
9	Ra	06	09	15	09	11	10	08
	Rb	28	15	20	26	20	18	25
10	Ra	05	02	04	08	06	10	05
	Rb	14	24	20	09	29	25	38
11	Ra	00	05	06	07	08	07	08
	Rb	34	29	32	34	31	29	33
12	Ra	03	01	10	05	05	09	05
	Rb	17	30	23	32	35	34	35
13	Ra	04	08	08	05	09	13	05
	Rb	16	15	27	16	29	29	38
14	Ra	07	08	10	14	06	07	07
	Rb	26	31	13	26	30	32	22

Table A-4

The Pecking Rates to the Test Stimulus (Ra) and the Comparison Stimulus (Rb) on Each Trial for Bird 20

		Test Stimuli						
Cycle		1	2	3	4	5	6	7
1	Ra	00	22	23	12	04	01	03
	Rb	00	25	19	20	27	21	28
2	Ra	03	08	29	00	01	01	00
	Rb	33	16	19	15	23	14	18
3	Ra	08	13	21	03	00	00	04
	Rb	17	29	24	18	09	16	14
4	Ra	10	00	12	01	00	00	02
	Rb	20	08	15	26	21	16	20
5	Ra	00	03	04	02	00	00	00
	Rb	18	17	17	15	23	15	13
6	Ra	00	00	13	00	00	00	00
	Rb	18	23	23	18	20	18	20
7	Ra	04	02	04	00	00	00	00
	Rb	18	22	30	17	20	25	15
8	Ra	00	00	03	00	00	00	00
	Rb	19	30	22	19	18	19	24
9	Ra	02	03	07	00	00	00	00
	Rb	21	20	23	15	12	12	20
10	Ra	00	00	07	01	00	00	01
	Rb	19	26	23	15	23	27	18
11	Ra	02	03	05	00	00	01	00
	Rb	25	26	26	17	25	30	20
12	Ra	01	00	05	00	00	00	00
	Rb	29	33	31	29	39	35	27
13	Ra	00	00	03	01	00	00	01
	Rb	31	22	25	33	20	20	23
14	Ra	00	04	05	00	00	03	02
	Rb	28	27	29	23	32	25	21

Table A-5

The Pecking Rates to the Test Stimulus (Ra) and the Comparison Stimulus (Rb) on Each Trial for Bird 21

		Test Stimuli						
Cycle		1	2	3	4	5	6	7
1	Ra	17	23	21	30	13	00	03
	Rb	87	79	71	65	112	00	100
2	Ra	10	13	20	32	00	07	09
	Rb	81	69	69	70	104	89	61
3	Ra	00	10	15	35	04	00	02
	Rb	74	71	75	55	80	79	67
4	Ra	09	09	22	00	00	00	07
	Rb	81	12	53	00	00	38	76
5	Ra	09	16	17	33	00	00	13
	Rb	71	82	61	58	74	90	51
6	Ra	01	00	23	41	16	23	00
	Rb	69	68	56	38	54	62	71
7	Ra	00	00	01	25	01	02	00
	Rb	70	55	77	44	68	68	77
8	Ra	07	01	01	39	17	00	02
	Rb	70	55	77	53	73	71	71
9	Ra	00	04	00	10	09	01	00
	Rb	80	70	72	65	58	76	75
10	Ra	00	12	00	01	33	13	00
	Rb	78	68	83	75	48	64	70
11	Ra	00	01	15	16	11	12	00
	Rb	80	78	62	54	77	65	67
12	Ra	00	00	01	28	00	00	00
	Rb	70	65	69	54	58	41	66
13	Ra	00	00	00	01	00	00	02
	Rb	72	80	74	64	60	85	64
14	Ra	00	00	20	55	00	00	11
	Rb	55	50	53	49	63	58	61

Table A-6

The Pecking Rates to the Test Stimulus (Ra) and the Comparison Stimulus (Rb) on Each Trial for Bird 22

Cycle		Test Stimuli						
		1	2	3	4	5	6	7
1	Ra	07	00	21	09	16	02	20
	Rb	33	00	34	35	30	38	26
2	Ra	06	28	23	15	25	24	05
	Rb	28	21	29	41	23	26	31
3	Ra	12	07	25	17	00	27	00
	Rb	22	23	21	24	23	22	11
4	Ra	00	08	06	09	00	05	00
	Rb	02	19	04	09	04	21	02
5	Ra	05	13	00	04	06	27	07
	Rb	18	14	30	27	21	31	29
6	Ra	03	10	12	22	00	09	00
	Rb	29	22	21	19	17	19	04
7	Ra	00	00	01	01	07	00	00
	Rb	01	16	17	15	07	17	06
8	Ra	00	00	00	00	00	00	00
	Rb	12	00	00	00	09	00	00
9	Ra	00	00	00	00	00	00	00
	Rb	00	15	10	06	20	13	09
10	Ra	00	00	00	00	00	00	00
	Rb	14	15	00	02	14	00	17
11	Ra	00	00	00	00	00	00	00
	Rb	05	14	15	09	00	14	00
12	Ra	00	00	00	00	00	00	00
	Rb	13	00	03	08	14	00	20
13	Ra	00	00	00	00	00	00	00
	Rb	15	14	16	11	10	10	17
14	Ra	00	00	00	00	00	00	00
	Rb	00	09	16	07	00	10	06

Table A-7

The Pecking Rates to the Test Stimulus (Ra) and the Comparison Stimulus (Rb) on Each Trial for Bird 23

		Test Stimulus						
Cycle		1	2	3	4	5	6	7
1	Ra	35	20	25	00	67	53	29
	Rb	40	36	40	00	28	33	35
2	Ra	17	22	28	49	53	54	32
	Rb	41	53	32	33	30	32	24
3	Ra	06	15	21	38	42	34	12
	Rb	51	39	28	37	28	34	41
4	Ra	12	11	14	30	51	53	01
	Rb	40	48	43	42	16	26	45
5	Ra	08	15	09	44	34	38	04
	Rb	43	38	40	12	32	29	30
6	Ra	14	20	00	42	28	45	18
	Rb	29	35	02	22	28	31	37
7	Ra	14	00	00	06	24	30	04
	Rb	36	41	54	16	38	34	37
8	Ra	00	08	18	30	28	29	03
	Rb	40	39	31	32	30	36	36
9	Ra	00	00	03	15	06	22	07
	RB	54	35	37	44	45	34	35
10	Ra	00	00	00	01	02	14	00
	Rb	49	51	48	49	50	56	50
11	Ra	03	00	02	10	12	03	04
	Rb	39	46	45	53	42	50	38
12	Ra	01	10	04	14	13	15	00
	Rb	45	47	48	39	36	42	45
13	Ra	00	02	01	16	09	11	00
	Rb	47	36	49	38	46	43	37
14	Ra	01	00	03	04	04	04	00
	Rb	48	37	45	31	45	40	45

Table A-8

Expected Rates of Reinforcement (S*b Ra/Rb) for Each Stimulus by Trial for Bird 17

	Test Stimuli						
Cycle	1	2	3	4	5	6	7
1	.088	.279	.063	.123	.369	.234	-
2	.250	.145	.194	.129	.145	.162	.201
3	.121	.132	.159	.128	.085	.085	.294
4	.256	.109	.118	.220	.179	.138	.147
5	.138	.238	.120	.173	.125	.336	.289
6	.141	.094	.087	.125	-	.180	.167
7	.121	.214	.338	.183	.149	.156	.225
8	.020	.050	.115	.057	.053	.051	.080
9	.194	.048	.064	.061	.186	.095	.108
10	-	-	-	-	-	-	.034
11	-	-	-	-	-	-	-
12	.140	.127	.073	.029	.029	.033	-
13	.065	.210	.038	.250	.041	.042	.064
14	.023	-	-	-	-	-	.065

Table A-9

Expected Rates of Reinforcement (S*b Ra/Rb) for Each Stimulus by Trial for Bird 18

	Test Stimuli						
Cycle	1	2	3	4	5	6	7
1	.205	.180	-	.156	.157	.206	.221
2	.156	.133	.099	.148	.058	.316	.037
3	.136	.148	.050	.032	.105	.103	.028
4	.103	.054	.202	.074	.081	.138	.058
5	.074	.125	.066	.132	.045	.093	.152
6	.079	.125	.121	.090	.044	.093	.053
7	.043	.049	.034	.092	.069	.053	.043
8	.069	.061	.090	.116	.045	.063	.017
9	.119	.076	.079	.111	.101	.023	.011
10	.068	.071	.028	.086	.083	.023	.051
11	.037	.051	.053	.092	.153	.066	.029
12	.086	.044	.100	.103	.007	.000	.000
13	.008	.000	.070	.027	.041	.007	.000
14	.013	.088	.017	.051	.021	.007	.000

Table A-10

Expected Rates of Reinforcement (S*b Ra/Rb) for Each Stimulus by Trial for Bird 19

	Test Stimulus						
Cycle	1	2	3	4	5	6	7
1	.212	.087	.104	.125	-	.087	.046
2	.118	.146	.333	.274	.159	.143	.087
3	.308	.353	.073	.227	.133	.116	.045
4	.141	.268	.112	.193	.442	.065	.091
5	.100	.050	.055	.097	.107	.075	.063
6	.046	.173	.159	.098	.119	.177	.063
7	.052	.060	.131	.052	.113	.120	.018
8	.078	.075	.115	.100	.045	.114	.107
9	.054	.150	.188	.087	.138	.139	.080
10	.089	.021	.050	.222	.052	.100	.033
11	.000	.043	.047	.052	.065	.060	.061
12	.044	.008	.109	.039	.036	.066	.036
13	.063	.133	.074	.078	.076	.112	.033
14	.067	.065	.192	.135	.050	.055	.080

Table A-11

Expected Rates of Reinforcement (S*b Ra/Rb) for Each Stimulus by Trial for Bird 20

	Test Stimulus						
Cycle	1	2	3	4	5	6	7
1	-	.220	.303	.150	.037	.012	.027
2	.023	.125	.382	.000	.011	.018	.000
3	.118	.112	.219	.042	.000	.000	.071
4	.125	.000	.200	.010	.000	.000	.025
5	.000	.044	.059	.033	.000	.000	.000
6	.000	.000	.141	.000	.000	.000	.000
7	.056	.023	.033	.000	.000	.000	.000
8	.000	.000	.034	.000	.000	.000	.000
9	.024	.038	.076	.000	.000	.000	.000
10	.000	.000	.076	.067	.000	.000	.014
11	.020	.029	.048	.000	.000	.008	.000
12	.009	.000	.040	.000	.000	.000	.000
13	.000	.000	.030	.008	.000	.000	.011
14	.000	.037	.043	.000	.000	.030	.024

Table A-12

Expected Rates of Reinforcement (S*b Ra/Rb) for Each Stimulus by Trial for Bird 21

	Test Stimulus						
Cycle	1	2	3	4	5	6	7
1	.049	.073	.074	.115	.029	-	.008
2	.031	.047	.072	.114	.000	.020	.037
3	.000	.035	.050	.159	.013	.000	.007
4	.028	.000	.104	-	-	.000	.023
5	.032	.049	.070	.142	.000	.000	.064
6	.004	.000	.103	.270	.074	.093	.000
7	.000	.000	.003	.142	.004	.007	.000
8	.025	.003	.004	.184	.058	.000	.007
9	.000	.014	.000	.039	.039	.003	.000
10	.000	.044	.000	.003	.172	.051	.000
11	.000	.003	.061	.074	.036	.046	.000
12	.000	.000	.004	.130	.000	.000	.000
13	.000	.000	.000	.004	.000	.000	.008
14	.000	.000	.009	.281	.000	.000	.045

Table A-13

Expected Rates of Reinforcement (S*b Ra/Rb) for Each Stimulus by Trial for Bird 22

	Test Stimulus						
Cycle	1	2	3	4	5	6	7
1	.053	-	.154	.064	.133	.013	.192
2	.054	.333	.198	.092	.272	.231	.040
3	.136	.076	.298	.177	.000	.307	.000
4	-	.105	-	-	-	.059	-
5	.069	.232	.000	.037	.071	.218	.060
6	.026	.114	.143	.289	.000	.118	-
7	-	.000	.015	.017	.250	.000	-
8	-	-	-	-	-	-	-
9	-	.000	.000	.000	.000	.000	-
10	-	.000	-	-	.000	-	.000
11	-	.000	.000	-	-	.000	-
12	.000	-	-	-	.000	-	.000
13	.000	.000	.000	.000	.000	.000	.000
14	-	.000	.000	-	-	.000	-

Table A-14

Expected Rates of Reinforcement (S*b Ra/Rb) for Each Stimulus by Trial for Bird 23

	Test Stimulus						
Cycle	1	2	3	4	5	6	7
1	.219	.139	.156	-	.598	.402	.207
2	.104	.104	.219	.371	.442	.422	.333
3	.029	.096	.188	.257	.375	.250	.073
4	.075	.057	.081	.179	.797	.510	.072
5	.047	.099	.056	.917	.266	.328	.033
6	.121	.143	-	.477	.250	.362	.122
7	.097	.000	.000	.094	.158	.221	.027
8	.000	.051	.145	.234	.233	.201	.021
9	.000	.000	.020	.085	.033	.162	.050
10	.000	.000	.000	.005	.010	.063	.000
11	.019	.000	.011	.047	.071	.015	.026
12	.056	.053	.021	.090	.090	.089	.000
13	.000	.014	.005	.105	.049	.064	.000
14	.005	.000	.017	.032	.022	.025	.000

THE EFFECTS OF EXTINCTION ON RESPONSES TO GENERALIZED AND CONDITIONED STIMULI IN PIGEONS

by

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Abstract

An experiment was designed to test the hypothesis that the rate of extinction increases as the differences between training and test (generalized) stimuli increases when the response measure has ratio scale properties. The response measure (Rt / Rc) represents the rate of pecking to the test stimulus divided by rate to a comparison stimulus which the bird has a constant tendency to peck. These measures are assumed to be on a scale with approximately ratio properties. Seven evenly spaced stimuli on the hue dimension were employed. Two stimuli were the conditioned stimuli, and the other five stimuli were the generalized stimuli. Pigeons were trained on a concurrent VI-240 s VI-240 s schedule in which a comparison stimulus was on one response key while the two conditioned stimuli were alternately on the other key. Subsequently, the pigeons were given generalization tests in which pecks to the comparison stimulus continued to be reinforced on a VI-240 s schedule and the seven test stimuli were presented one at a time on the other key. Pecks to test stimuli were never reinforced. For analysis, the stimuli were grouped into comparable pairs (a) the conditioned stimuli (3 & 5), (b) a pair one-step removed from the conditioned stimuli (2 & 6), and (c)

the pair two-steps removed (1 & 7). The initial values of Rt / Rc were lower as the difference between training and test stimuli increased from zero to two steps, and the effect of the steps was statistically significant. The relative rates as a function of number of previous test trials were found to fit a decay-function model reasonably well. Finally, results obtained using parameter estimation failed to indicate any differential extinction rate among the three pairs of stimuli. Thus, the hypothesis was not supported.